CHAPTER VI. DISCUSSION

Overall assessments of the IX system's performance are based on the quality and quantity of process water softened for an amount of salt used for regeneration. The terms "quality" and "quantity" refer to calcium leakage and volume of water softened for a volume of resin, respectively, while the amount of salt used in regeneration refers to sodium volume passing through the bed in regeneration.

IX system performance is actually a measure of total plant performance, since the IX process is dependent on upstream clarification and filtration processes and downstream desalting processes. For the IX system to have low calcium leakages, the brine generated for regeneration must meet both volumetric and quality requirements.

Performance results for Los Banos operations were presented and briefly discussed in the previous section. These results were based on daily samples taken from clearwell or brine tanks, including all chlorinated and brine waters which inadvertently entered the clearwells. Generally, the chlorination flowrate was in the range of 7 to 11 gpm. Periodically, calcium and hardness analyses were also performed on the effluent to verify actual leakage.

Due to the changing feedwater conditions, development of the process, and other planned and unplanned activities that introduced a myriad of variables, the IX desalting process was never operated under steady-state conditions for the process to reach an equilibrium condition. The process needs to be operated in a steady-state condition to further refine operation parameters and determine the resin's operating capacity and life when subjected to extreme conditions as would be encountered. The information gathered from operations at Los Banos forms the basis for future studies and has given significant knowledge in the areas of programming and controlling, modeling, monitoring, selection of equipment, and identification of problems encountered.

Programming and Controlling

The initial computer operations program was a fairly simple one that allowed only for durations of the events to be input for a two-unit operation. Through operations, this program proved to be too inflexible to coordinate the batch process of the IX system between the two continuous processes -- clarification/filtration and desalting. The control program was modified as necessary based on the information in the previous section. The operations program was based upon the following criteria:

1. Limiting of waste volumes to be disposed of. (Waste consists of rinse water and waste brine.)

2. Setting a maximum process water concentration limit at one bed volume. The time frame in which the bed volume is generated is dependent on the volume of water softened in a cycle and the flowrates of the desalting units.

3. Establishing a minimum service factor of 50 percent at maximum softening flowrate.

4. Determining that the amount of sodium in the volume of fresh reject brine used in regeneration equals the amount of total hardness removed during softening. Inherent in this condition is the knowledge that the sodium concentration must be "N" times the total hardness concentration to provide the driving force necessary for the exchange of ions to occur. "N" depends upon resin, feedwater, and brine characteristics.

5. Determining that the total duration of brine settling and transfer of the used brine to the recycled brine tank is equal to or less than the duration of the softening (service) event.

By the time the system was shut down, the system could be run reliably for a variety of test conditions. The operations program had the capability to:

1. Operate one or both units continuously or just a single cycle for either or both units.

2. Change any of the cycle event durations.

3. Provide service flowrates of 110 or 230 gpm.

4. Provide fresh brine regeneration event flowrates of 75 or 150 gpm.

5. Delay regeneration when the unit or units were run in the continuous mode. This feature allowed for the service event to be performed directly after regeneration and rinsing. Experience dictated that this delay was necessary because leaving the rinse water in contact with the resin for any length of time after regeneration resulted in an early hardness breakthrough. "Regeneration delay" is Option 4 in the special options menu of the IX operations program and only necessary for the 110-gpm flowrate.

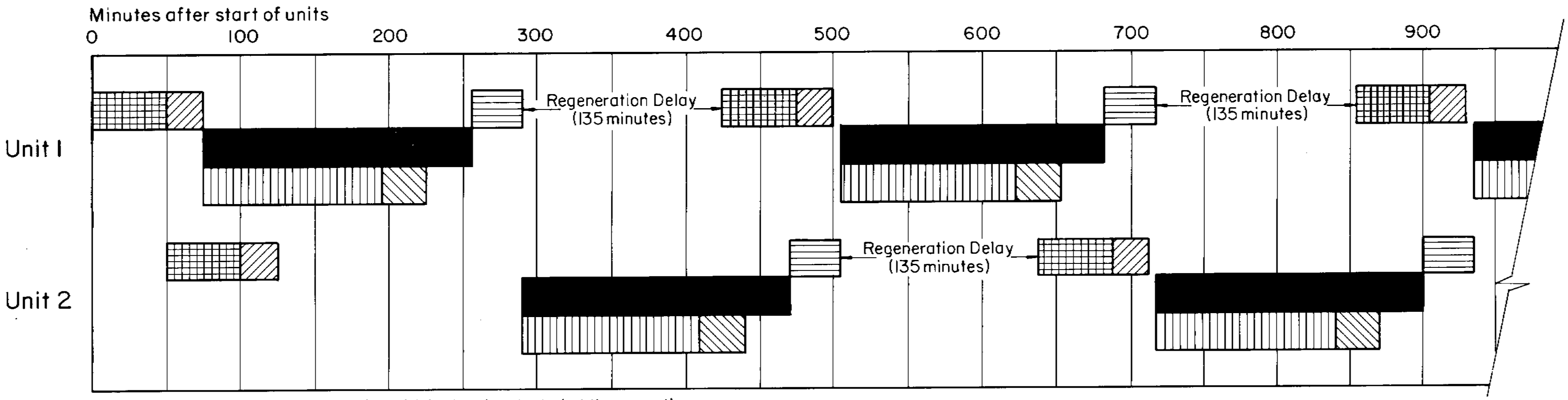
6. Delay the start of the IX cycle to coordinate the operation of the IX with desalting system operations. This delay is Event 12 of the IX cycle.

The flexibility of operating the IX system under various desalting scenarios is shown by the bar graphs of Figures 19 and 20. Figure 19 shows the 92-gpm desalting scenario as shown on Figure 16, whereas Figure 20 shows the 210-gpm desalting scenario as shown on Figure 17. Event durations corresponding to the bar graphs are shown on Table 16 and were developed as part of the testing program for Tests 1 and 3 previously described and found in Appendix F. Both IX units were started at the same time.

Another important feature of the operations program was the capability to transfer brine from either tank T2 or T3 to tank T4. This transfer was done by computer without interrupting other activities the computer was performing simultaneously.

The IX cycle developed consisted of 12 events -- three regenerations, four rinses, service, settling of brine, brine transfer, drain, and delay. The three regenerations and four rinses (two upflow and two downflow) were necessary to route the waters and brines to appropriate locations. This

Figure 19. IX Cycle for Desalting Test I



Note: Two-unit continuous operation with both units started at the same time.
IX service flow at 110gpm to give RO 2 flow at 92gpm.

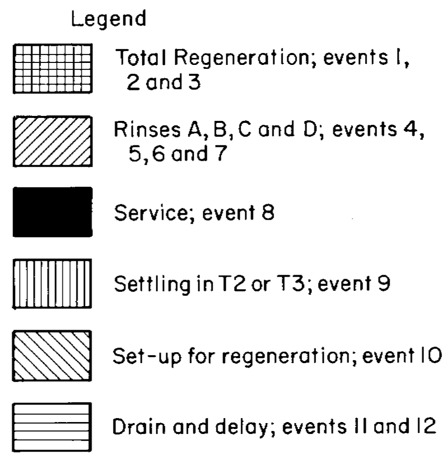
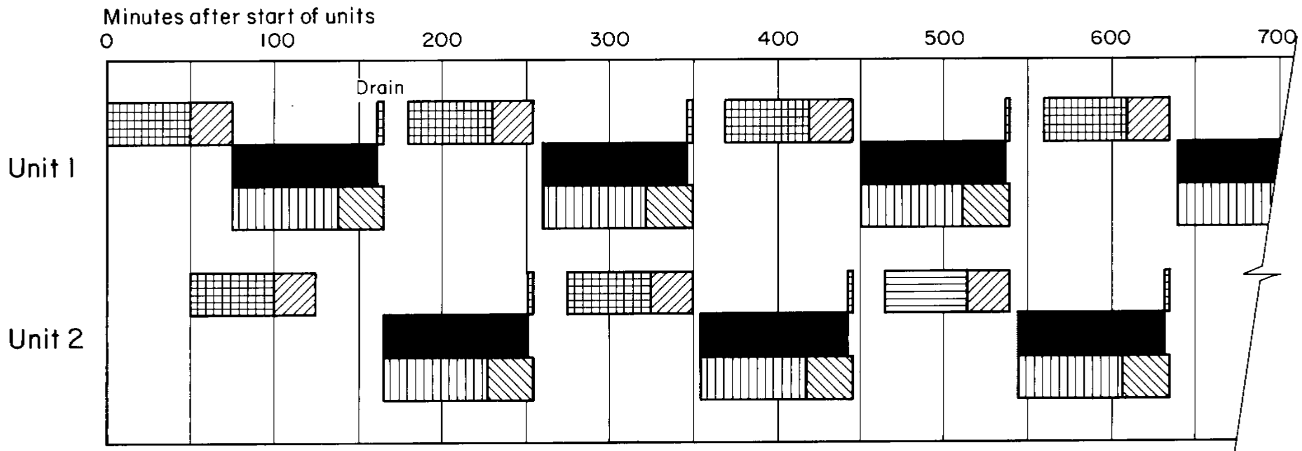


Figure 20. IX Cycle for Desalting Test 3



Note: Two-unit continuous operation with both units started at the same time.
IX service flow at 230gpm to give RO 1 flow at 210gpm.

TABLE 16

EVENT DURATIONS

Event Number	Event Description	Duration (minutes)	
		Figure 19	Figure 20
1	Recycled brine regeneration 1	10	13
2	Recycled brine regeneration 2	32	23
3	Fresh brine regeneration	8	14
4	Rinse A (upflow)	5	5
5	Rinse B (upflow)	4	4
6	Rinse C	0	0
7	Rinse D	16	16
8	Service	180	87
9	Settling in T2 or T3 during service	120	60
10	Setup for regeneration during service	28	28
11	Drain	3	3
12	Delay	32	0
--	Regeneration delay (secondary menu)	135	0

routing minimized dilution effects of rinse water on the used brine. Also, the upflow rinses allowed for the full volume of fresh brine to be pushed through the columns and saved for use in regeneration. For more information concerning the IX cycle, consult the three test plan schedules in Appendix F.

Modeling

A model was developed to simulate the operation of the IX desalting loop. The model calculated event durations and volumes of softened water and brines generated for an input IX desalting scenario. The program also determined operation schedules and flagged system constraints. An output of the model is located in Appendix H.

Monitoring

The addition of a printer helped detect programming bugs, equipment malfunctions, and other problems. The printer recorded the unit, event, and time that the event was put into operation. These data were extremely helpful in operations and system evaluation.

Selecting Equipment and Materials

Each IX column contained three manifolds or distributors -- top, middle, and bottom -- to equally distribute flow across the columns' cross-sections. Each manifold consisted of a 3-inch header and 1-inch PVC laterals projecting at right angles from the header. The bottom header was made of wrought steel, while the middle and top headers were fashioned from PVC. The laterals were covered with a PVC screen to prevent resin loss. The bottom manifold was located 10 inches above the concave-shaped column bottom. The interiors of the columns were coated with epoxy.

During the course of operations, all bottom manifolds made of PVC were replaced with stainless steel manifolds and screens on the laterals of top manifolds were taken off to allow solids to be removed from the columns during regeneration. In addition, interiors of the columns were resurfaced to repair corrosion damage while the bottom manifolds were being replaced.

There were two types of process control valves involved in the operation of the IX system. The original contract supplied butterfly valves, while ball valves were installed in the IX sump contract.

The computer-controlled butterfly valves operated as signaled after they were manually broken free following a long period of inoperation. Leakage through the butterfly valves did occasionally occur as a result of the contamination of the IX effluent clearwell with regenerant brine. The leakage was corrected when discovered and could have been detected by continuous monitoring for conductivity of the line.

The large ball valves (3 to 4 inches in size) were not reliable. They continually jammed and eventually had to be taken out of the operations program.

The flow control valves used to regulate flows through the columns were of the constant-rate, spring-loaded, pressure-differential type. Of the ten flow control valves used, only one failed to deliver flows within its specified range, and that condition lasted but a short time. Flows were determined by tank level differentials.

The flow monitoring sensors were of the paddlewheel type and were located to register flows from both directions. Although paddlewheel flow sensors were used to monitor one-directional flows in a number of places around the plant with good results, they did not register a constant flowrate for any reasonable length of time with the two-direction application even after being cleaned.

A sample of the IX resin was extracted from each of the columns in July 1986 and sent to the manufacturer for testing. The tests evaluated the condition of the resin as compared to new resin. Results of the tests indicated that the resin was in good condition, despite some indications of iron fouling. Three of the samples showed some slight chemical deterioration as measured by moisture content. The moisture content for the three samples were 49.0, 49.7, and 51.3 percent, while the typical range is from 44 to 48 percent. Performance problems do not normally occur until the moisture content exceeds 55 percent.

Many of the bolted steel tanks did not survive the course of testing without repair. Corrosion appeared in two forms -- sheet and spot. Sheet corrosion began at the edges of the steel tank plates and worked its way along the sheet under the coating. The coating could be peeled off in sheets or large flakes. Spot corrosion formed as spots on the bottom or sides of the tank where the coating was damaged during construction and maintenance activities. This corrosion created pinholes in the steel.

Precipitation in tank T4 caused regeneration to become less efficient when precipitate (calcium sulfate) was passed through the resin bed. Delayed precipitation resulted from either the addition of threshold inhibitors to the process water during the desalting process or a scheduling problem or from both.

The time allotted for mixing and settling was inadequate for the cycle developed. Also the precipitation process methodology and design were inadequate for this application.

The operations program and other information concerning the IX equipment are included in Appendix H.

CHAPTER VII. CONCLUSIONS

Ion exchange using brine from a desalting system for regeneration is a relatively simple concept, but extensive control and monitoring are required. The Los Banos facility's IX program demonstrated the capabilities of the process and identified a multitude of process and operational-related issues or problems to be resolved prior to design of a full-scale system.

The IX desalting process was unable to be demonstrated as a complete IX desalting "loop" and obtain a steady-state condition. Persistent problems encountered in the third desalting stage (EDR) impeded generation of regenerant brine in either concentration or volume, along with various other mechanical and operational difficulties. These problems prevented steady-state loop operation. Despite these problems, the IX system performed as expected. Calcium leakages were below 1 meq/L for an influent hardness of over 50 meq/L and sodium-to-hardness ratios of approximately 2:1 when the resin was properly regenerated.

Despite all the mechanical and process difficulties encountered, the operations at Los Banos successfully demonstrated and developed:

1. Removal of calcium by IX under extreme conditions such as high total hardness, sodium, and TDS concentrations.

2. Regeneration of the IX resin using a reject brine from desalting processes. This use of reject brine alleviates both the need to import regeneration salt and disposal of such.

3. An IX operation cycle which minimizes wastes.

4. Operation constraints and parameters for a process treatment train to desalt agricultural drainage water. These constraints and parameters involve operation of the process train to "manufacture" brine sufficient in quality and quantity for use in the regeneration of the IX resin.

5. A model for the IX desalting process.

CHAPTER VIII. RECOMMENDATIONS

The Los Banos project was the result of years of study in the treatment and disposal of agricultural drain water. The IX desalting process is a unique process which was never before tested on this scale. Many of the problems encountered were design and operation oriented. With these problems identified, the overall recommendation is to continue to develop the IX desalting process and operate it at steady-state loop conditions. Future testing should investigate limits of the process (not equipment or operations) and include:

1. Determination of the limit to which the process water can be concentrated and yet maintain adequate calcium leakage.

2. Investigation of resin life and ability of resin to maintain removal capacity with time.

3. Determination of the effect of anti-scaling chemicals on regeneration and in the precipitation of salts of the recycle brine.

4. Determination of the effects of alum, cationic polymers, and other flocculation/coagulation aid carryover from the clarification/filtration processes on the IX process.

5. Investigation of salt-harvesting schemes to precipitate salts from the brines.

In addition to the recommendations stated above, modeling should be included as an integral portion of the testing program. The IX desalting model developed at Los Banos should be expanded to include the entire IX desalting (loop) treatment process. Provisions should be made to calculate constituent concentrations, salt saturation, or any other indices at various points in the process to determine where problems arise. The model could form the basis for an operations control program for the entire IX desalting treatment process.

As previously stated, many of the problems encountered in the IX system were design and operational based. Design recommendations for IX systems used in future testing should include:

1. Proper selection of material and equipment for the intended use.

2. Viewing ports on IX columns to verify flow regimes.

3. A bottom manifold placed as close to the bottom of the column as possible so that the entire resin can be utilized.

4. Monitoring of all flows, in-line process water effluent conductivity, and brine tank levels.

5. Location of flow sensors where flows can be accurately and reliably measured.

6. Operation and monitoring of the IX process by computer. The computer should be equipped with an individual power supply and printer.

7. Facilities to precipitate calcium sulfate from the recycle brine stream(s).

8. Facilities to make and adequately mix sodium chloride brine for start-up and emergency purposes.

REFERENCES

California Department of Water Resources. *Agricultural Waste Water Reverse Osmosis Pretreatment.* August 1983.

California Department of Water Resources and University of California. *Agricultural Waste Water for Power Plant Cooling, Development and Testing of Treatment Processes.* Volume II. June 1978.

Calmon, Calvin, et al. (eds.). *Ion Exchange for Pollution Control.* Volume I. CRC Press, Inc. 1979.

Diamond Shamrock. *Duolite Ion Exchange Resins, C-20 for Softening Water.* Duolite Data Bulletin 24. 1981.

Dorfner, Konrad. *Ion Exchangers -- Properties and Applications.* Ann Arbor Science Publishers, Inc. Third Printing. 1977.

Dow Chemical Company. *Water Conditioning Manual, Dowex Ion Exchange Resins.* 1981.

Laird, Alan D. K. *Field Testing of the Existing Wiped-Film Rotating-Disk Evaporator.* Quarterly Report for University of California, Berkeley/California Department of Water Resources Agreement B-55037. April 1985.

Rohm and Haas Company. *Amberlite IR-120 Type Cation Exchange Resins.* Technical Bulletin, Fluid Process Chemicals. March 1981.

United States Department of Interior, Bureau of Reclamation. *Wiped-Film Rotating-Disk Evaporator for Water Reuse.* Technical Completion Report. November 1982.

____. *Cation Exchange Pretreatment Studies for High Recovery, Yuma Desalting Plant.* October 1983.

____. *Cation Exchange Pretreatment Studies for La Verkin Springs.* August 1984.